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Evaluating Automatic Transmission Fluids

ALTHOUGH it was not realized at the time, the introduction of the Oldsmobile Automatic Safety Transmission in 1937 established the need for an entirely new type of lubricant. At first, an attempt was made to lubricate this transmission with motor oils which were of the straight-mineral type, with the exception that some contained oxidation inhibitors. This choice was logical because the engines of that time were lubricated satisfactorily with such oils and, moreover, little was known concerning additive-type fluids. However, service experience soon showed that a close relationship existed between automatic transmission fluid quality and actual transmission performance. Use of the straight-mineral type oils often resulted in sludge and varnish formation. Oil deterioration frequently progressed to the extent that transmission performance became sluggish, and, in some cases, the units became inoperative.

The introduction of the Hydra-Matic transmission in 1939 served to emphasize the deficiencies of the straight-mineral type oils and other fluids of the day. As the shortcomings became more obvious and as it became apparent that the number of automatic transmissions in use would be increasing yearly, General Motors Research began work on the necessary steps preliminary to the formulation of a specification which, for the first time, would define the specific characteristics and properties desired of automatic transmission fluids and which would list the tests necessary to insure that the fluids would fulfill these requirements.

In 1949, the first Type A Specification was issued. In the program for qualifying fluids against this Type A Specification, General Motors Research enlisted the services of the Armour Research Foundation of The Illinois Institute of Technology. Arrangements were made for some of the qualification tests to be continued by Armour and some by General Motors. Fluids so qualifying were identified by an "Armour Qualification Number", commonly called "AQ Number", assigned to the fluid. This identification, labeled on each container, assured the customer that unsatisfactory fluids had been eliminated and, at the same time, provided him with the means of identifying qualified fluids.

In 1951, the original Type A Specification was modified, particularly with respect to viscosity, viscosity index, flash point and fire point, to make it more realistic in the light of experience gained during the intervening two years. This 1951 version of the specification remained essentially unchanged until November 1, 1957, when the Type A *Suffix A* Specification was issued. As indicated in Table I, a further modification on August 11, 1958 resulted in the current specification.

The purpose of this article is to incorporate, within one source, an outline* and discussion of methods which either have been used or are being considered for use in evaluating automatic transmission fluids and to present data obtained with

* This article is a severe condensation of Technical Paper SP-161 of the same title which was presented before the Annual Meeting, Society of Automotive Engineers at Detroit on January 14, 1959, and is available from the Society.

TABLE I
AUTOMATIC TRANSMISSION FLUID, TYPE A SUFFIX A IDENTIFICATION SPECIFICATION REQUIREMENTS

November 1, 1957

Requirements printed in italics were eliminated by August 11, 1958 letter from General Motors Committee on Automatic Transmission Fluid.

a. Miscibility	Pass
b. Viscosity, Saybolt Universal, 210°F.	49 seconds, min.
c. *Viscosity, Saybolt Universal, 0°F.*	*7,000 seconds, max. (Note A)*
d. Flash Point, °F.	320 minimum
e. Fire Point, °F	350 minimum
f. Low Temperature Fluidity	Pass
g. Copper-Strip Test, 3 hrs. at 300°F.	Pass
h. Anti-Foaming Properties	Pass
i. Heating Test	Pass
j. Non-Corrosion and Non-Rusting Properties	Pass
k. Effect on Seals	Pass
l. Odor	Pass
m. Non-Toxic Properties	Pass
n. Oxidation Test on Fluid as Marketed	Pass
o. *Oxidation Test on Fluid diluted with equal volume of Reference Oil*	*Pass*
p. Non-Chatter or Squawking Properties	Pass
q. Durability (Cycling) Test	Pass
r. Viscosity Stability, viscosity during and at conclusion of durability (Cycling) and performance tests, Saybolt Universal, 210°F.	46.5 seconds, min.
Saybolt Universal, 0°F.	*7,000 seconds, max. (Note A)*
s. Frictional Properties	Pass
t. Performance in Transmissions Under Service Conditions	Pass
u. Performance in Transmission Installed in Car and Tested in Cold Room at −10°F.	Pass

Note A: The viscosity at 0°F. is determined by extrapolation from viscosities determined at 100°F. and 210°F., using ASTM Chart A (D-341-43).

these methods at a large petroleum research laboratory. In the space allotted, it will be impossible to present all details of all test methods. This article, therefore, will be limited to a discussion of the major techniques and test methods used in determining automatic transmission fluid properties, with special emphasis being placed upon the *performance* type tests. For brevity, the ASTM (American Society for Testing Materials) and other standard test procedures not developed specifically for automatic transmission fluids will not be discussed except where pertinent data are presented.

FOAM TEST

The efficiencies of torque conversion, valving, shifting and indeed the entire performance of automatic transmissions are dependent upon the almost complete absence of foam at all times. Also, since foaming results from the very intimate mixing of large amounts of air with oil, it may exert a significant effect on oxidation stability.

A foam test using an apparatus designed by the Detroit Transmission Division of General Motors and shown in Figure 1, is required by the Type A Specification. The equipment consists of an immersion heater, a circulating system and a motor-driven pump and agitating device, all encased in a glass-windowed container. The passing limits of this foam test have changed throughout the years. At one time, a maximum of ½" foam height and 30 seconds collapse time were permitted. More recently, the major criterion has been the time required for

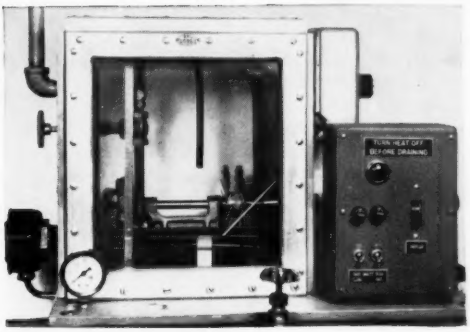

Figure 1 — Detroit Transmission Division Foam Test Apparatus.

the appearance of the first patch of clear fluid, free from all bubbles.

RUBBER SEAL TEST

The need for suitable compatibility between the automatic transmission fluid and the seal materials used in transmissions was recognized during the early development of the units. In the past, seal and fluid compatibility has generally been determined from the combination of the following type tests:

1. The ASTM Type Method specified in the Type A Specification.
2. The SAE Rotating Shaft Seal Test.
3. The condition of seals in transmission tests, such as Durability Cycling Tests and the Motored Transmission Tests.
4. The condition of seals in transmissions used in road and service tests.

The ASTM Type Tests can be run at different temperatures for varying lengths of time and can be used to show differences between fluids in regard to their effect on seal characteristics, including swelling, hardening, cracking and tensile strength. One of the main correlations established for this test is the relation of seal swell characteristics to fluid aniline point, a measure of paraffinicity. This relationship is illustrated in Figures 2 and 3 which show data obtained after 70 hours at 250°F. and

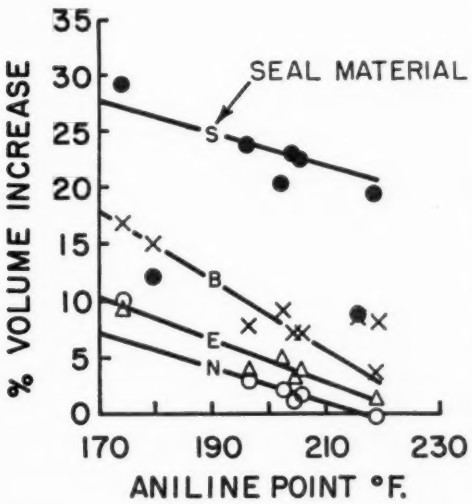

Figure 2 — Effect of fluid aniline point on swelling of four seal materials after 70 hours at 250°F.

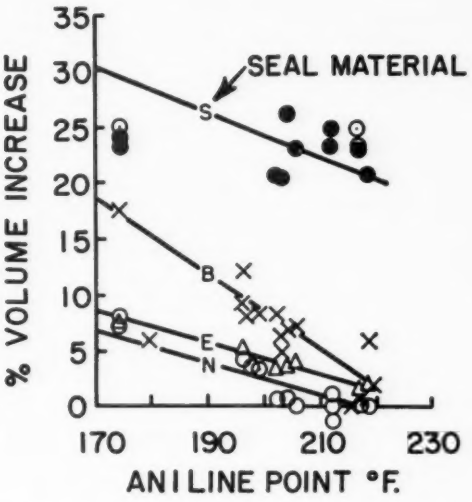

Figure 3 — Effect of fluid aniline point on swelling of four seal materials after 168 hours at 300°F.

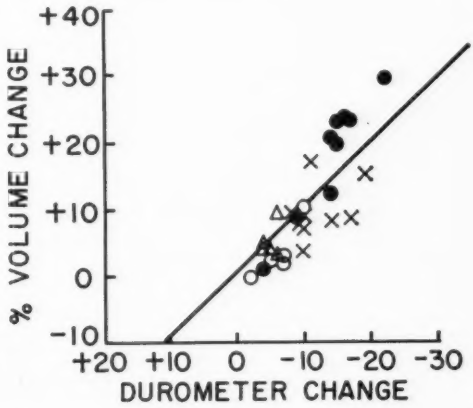

Figure 4 — Relationship between durometer hardness and swelling after 70 hours at 250°F.

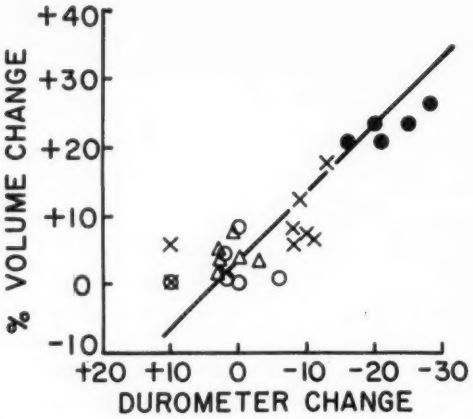

Figure 5 — Relationship between durometer hardness and swelling after 168 hours at 300°F.

168 hours at 300°F. It is interesting to note that the amount of seal swell did not change significantly with either time or temperature. However, it should be noted that, although there is a correlation between seal swell and aniline point for a given seal material, the actual levels and rates of change vary widely for different types of materials.

Figures 4 and 5 show the relationship existing between seal swelling, as measured by volume change, and hardness, as measured by durometer change. Again, these data were obtained after 70 hours at 250°F. and 168 hours at 300°F. and neither time nor temperature seem to exert an appreciable influence. It is evident that, as seals tend to swell, they generally tend to soften.

The SAE Rotating Shaft Seal Test is preferred for evaluation purposes by the manufacturers of some types of seals. It does have the advantage of more nearly simulating the conditions which exist for rotating shaft type seals.

Of the laboratory methods in use, the transmission tests, either the motored type or the engine-driven durability cycling type, would be expected to yield the most reliable information on actual seal performance. However, the repeatability and reproducibility with respect to seal performance are not always what might be desired.

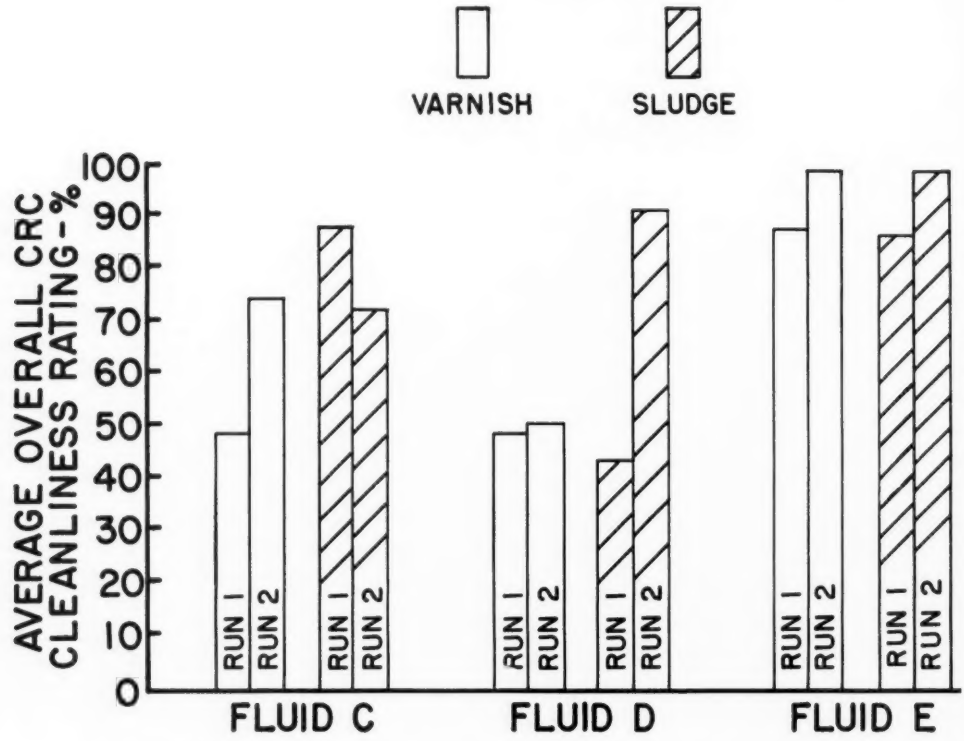

Figure 6 — Transmission cleanliness ratings on three fluids after Powerglide Oxidation tests.

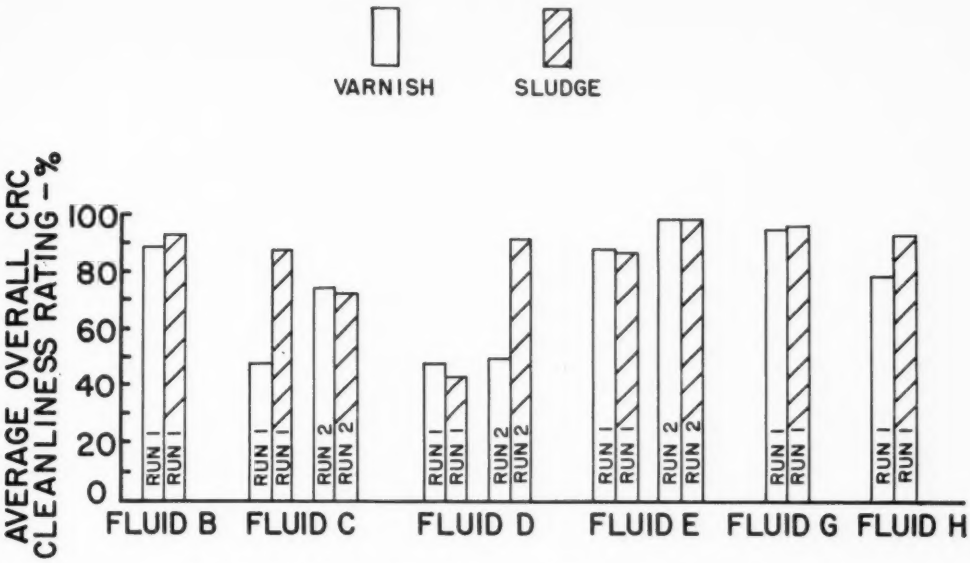

Figure 7 — Discriminating ability of Powerglide Oxidation Test among six fluids.

TYPE A OXIDATION TESTS

Chevrolet L-4

In the Type A Specification, the Chevrolet L-4 Oxidation Test, which is run in an engine, is the method specified for evaluating the high temperature oxidation resistance of automatic transmission fluids. Although the L-4 Test has been generally satisfactory, there are several shortcomings apparent in its use for establishing the oxidation resistance

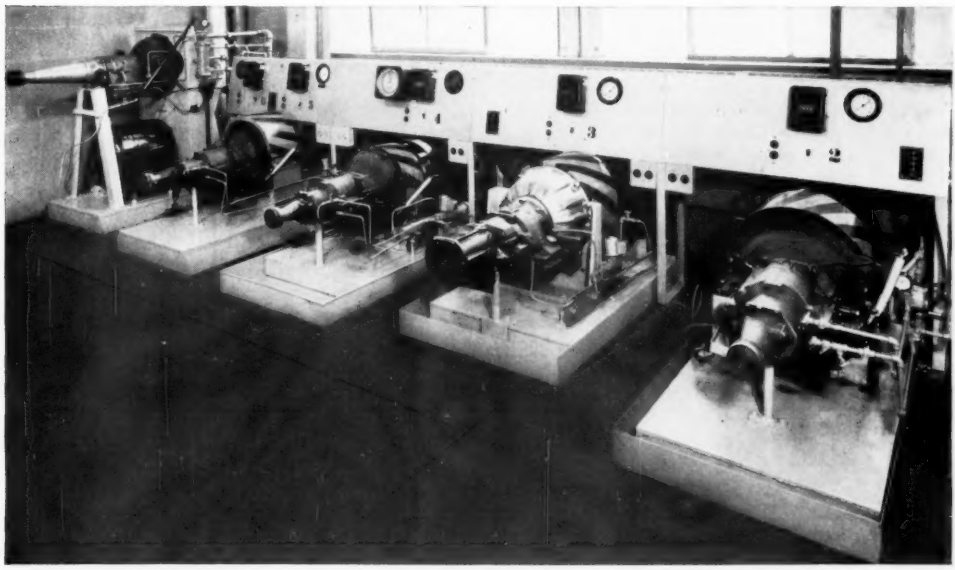

Figure 8 — Five motor-driven automatic transmissions used in laboratory tests on automatic transmission fluids.

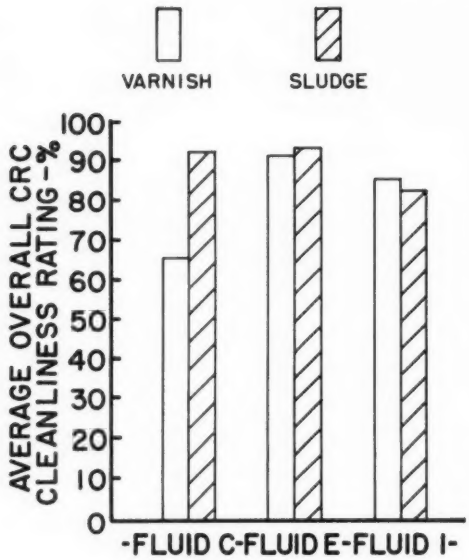

Figure 9 — Discriminating ability of 200 hour 3-4-3 Jet-Away Cycling Test among three fluids.

of these fluids, the primary shortcoming being the lack of severity as applied to modern fluids designed for modern transmissions.

Powerglide

Because of the shortcomings of the L-4 Test as applied to automatic transmission fluids, General Motors issued, on November 1, 1957, the Automatic Transmission Fluid, Type A, Suffix A, identification specification. This Suffix A Specification is identical to the Type A Specification, with the exception that in Specification Requirement "n" of Table I, the CRC L-39 Test, more popularly known as the Powerglide Oxidation Test, has been substituted for the L-4 procedure.

Briefly, the L-39 procedure consists of driving a Powerglide transmission with an electric motor at a speed of 1750 rpm for 300 hours at an oil temperature of 275°F. The transmission is assembled with the stator reversed. This arrangement subjects the fluid to shear and generates considerable heat. The specified oil sump temperature is maintained by means of an oil cooler and the proper temperature controls.

At the end of the test, the thrust washers are checked for weight loss, the suction screen is checked for clogging, the clutch plates are examined for sticking and transfer of plate material, and all parts are rated for varnish and sludge by means of the CRC Varnish and Sludge Rating System. Figure 6 shows the overall cleanliness ratings of 2 runs each on 3 fluids. As can be seen, the repeatability obtained was not good. This factor is recognized by the industry, and the CRC (Coordinating Research Council) is engaged in a cooperative program designed to determine ways of improvement.

Figure 7 shows that, within the limitations imposed by somewhat poor repeatability, the discriminating ability of the Powerglide Oxidation test was fair. Results of runs on 6 fluids with known varying degrees of oxidation resistance are shown. As can be seen, the Powerglide test indicated the existence of significant differences in cleanliness ratings.

The technique of motor-driving a transmission at no load has also been applied to several other makes of automatic transmissions for the purpose of obtaining oxidation performance data in the various transmissions in which the fluids might be used.

Figure 8 illustrates a battery of motored transmission test stands in use at a major petroleum laboratory. The tests and the data obtained will be discussed briefly.

3-4-3 Jet-Away Cycling

During the early use of the Jet-Away Hydra-Matic, some sludging and fluid oxidation were encountered in service under severe operating conditions. To study this problem, the 3-4-3 Jet-Away Cycling Test was developed. Basically, this test consists of driving the transmission with an electric motor and cycling it through the 3-4-3 shift every 8 seconds. When the test was originally developed, a duration of 100 hours was specified. It soon became apparent that a 200-hour duration was more realistic. Figure 9 indicates that the 200-hour test was capable of discriminating between fluids. Figure 10 however, indicates that the repeatability was not all that could be desired.

Merc-O-Matic

The Merc-O-Matic Oxidation Test was conducted

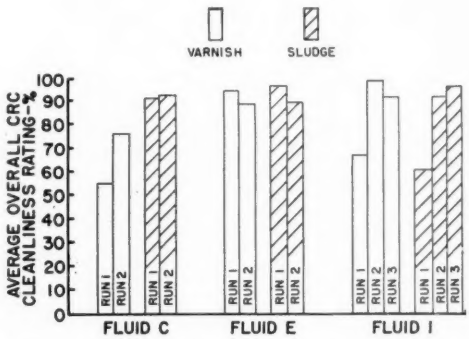

Figure 10 — Repeatability of 200 hour 3-4-3 Jet-Away Cycling Test.

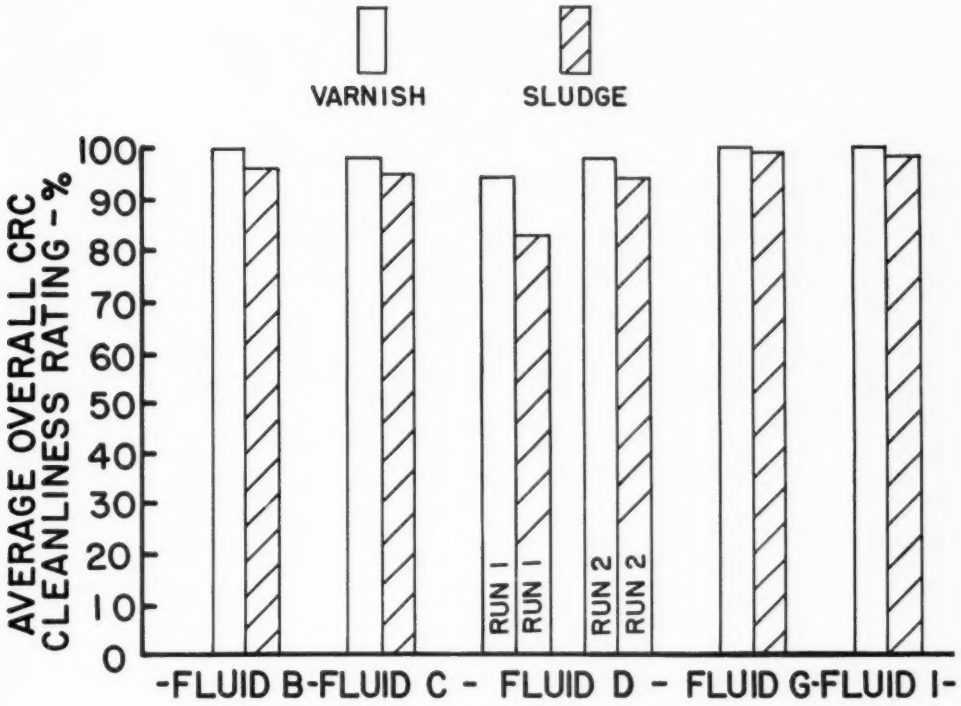

Figure 11 — Discriminating ability of Merc-O-Matic Test among five fluids.

with a 1957 Merc-O-Matic transmission with the stator, but not the sprag clutch, reversed.

Figure 11 shows the results obtained on 5 fluids which have been mentioned in connection with the Powerglide and Jet-Away procedures. The small differences between the ratings on the 5 oils indicates some lack of ability of the test to discriminate at the 275°F. temperature. Also, duplicate runs on Fluid D indicated some lack of repeatability. However, more runs would be required before any definite conclusions could be drawn regarding either aspect.

Dynaflow

A 1957 Dynaflow transmission was used for the Dynaflow Oxidation Test. Figure 12 shows the results obtained to date in a major petroleum laboratory. Although the number of tests thus far completed on any one fluid is not sufficient to permit an accurate determination of repeatability, the runs on the 4 fluids with previously-established differences in oxidation resistance indicate relatively good discrimination.

Torqueflite

The Torqueflite Oxidation Test was run with a 1957 Torqueflite transmission.

The number of fluids subjected to this test has not been sufficient to permit a determination of its discriminatory ability. Figure 13 shows the results of duplicate runs on the same fluid. On the basis of this limited information, it might be expected that

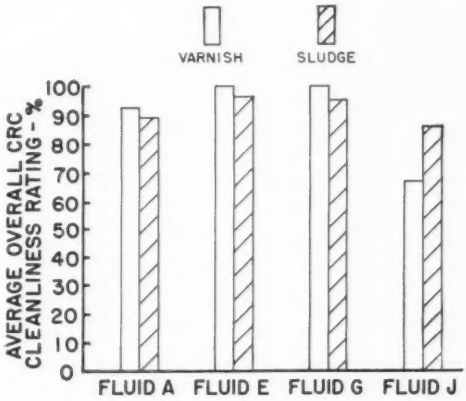

Figure 12 — Discriminating ability of Dynaflow Test among four fluids.

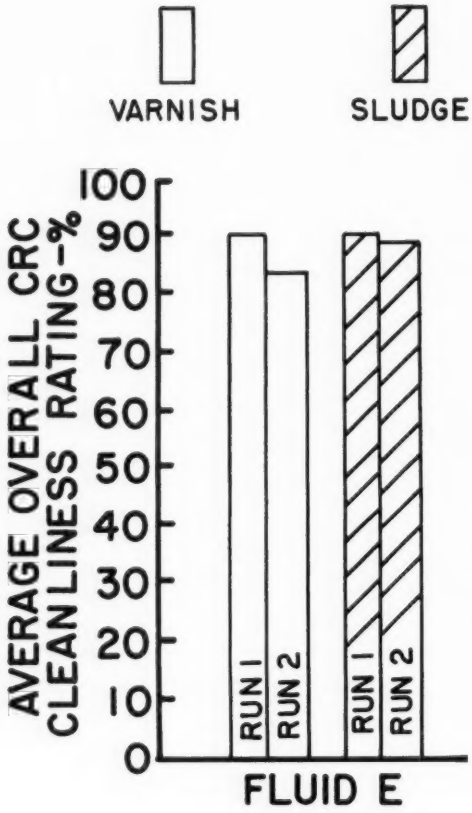

Figure 13 — Torqueflite transmission tests.

the repeatability of the Torqueflite would be acceptable. However, additional runs would be necessary before either the discriminatory or repeatability characteristics of the test could be established.

General

It is felt the foregoing data indicate that the oxidation performance of a given fluid may vary with the make of the transmission used for conducting the test. Results also seem to indicate that all the procedures require further investigation and refinement before any one can be used as a reliable and absolute evaluation method. With experience and use, the tests undoubtedly either have undergone or will undergo modifications which will make them more reproducible and practicable. However, in their present form, it is felt that the motored transmission tests are useful for evaluating automatic transmission fluids, *provided conclusions are based upon the results of several runs in one test or upon runs in each of several tests.*

DURABILITY CYCLING TESTS

The Durability Cycling Type Test is the laboratory test upon which most reliance has been placed in regard to judging the performance of automatic transmission fluids. There are a number of individual tests which fall into this general classification, since each transmission manufacturer, and in some instances, individual car divisions, have a test of this type. Basically, the tests are all very similar, but vary in detail of test conditions and equipment used. The following discussion of the Durability Cycling Type Tests will be restricted to the procedures which have been required or are being considered for the Type A Specification.

100 Hour Oldsmobile

The 100 Hour Oldsmobile Durability Cycling Test is the procedure which was in use prior to the issuance of the first Type A Specification until the latest revision issued November 1, 1957. This test consisted of driving contemporary Hydra-Matic transmissions with contemporary Oldsmobile engines. Full throttle accelerations were conducted from 600 to 3600 rpm in 45 seconds, followed by closed throttle decelerations back to 600 rpm in 15 seconds. This cycle was repeated once a minute for 6000 times, or for a total test duration of 100 hours. At the end of the test, the transmission was inspected for clutch plate condition, deposits and condition of seals and other component parts. Figure 14 illustrates the variation of clutch plate condition which may be experienced. This group of plates was selected as a reference standard for use in assigning numerical ratings.

50 Hour

By 1956, engine overspeeding in first and second gears, resulting from high engine output and low dynamometer torque characteristics, increased the difficulty of conducting the 100 Hour Durability Cycling Test to such an extent that changes in test conditions became necessary. As a result, the 50 Hour (or 2400 Cycle) Durability Cycling Test, using an inertia wheel in conjunction with the dynamometer, was developed. The use of the inertia wheel, as pictured in Figure 15, permitted the reduction in test time. This 50 Hour Test is the one which has been in use at Armour Research for Type A Qualification since 1956.

100 Hour Oldsmobile Inertia Wheel

Work now in progress is directed toward further modification of the Durability Cycling Test to use the latest Jet-Away Hydra-Matic with the Inertia Wheel Cycling Test procedure. As yet, the conditions for this test have not definitely been fixed.

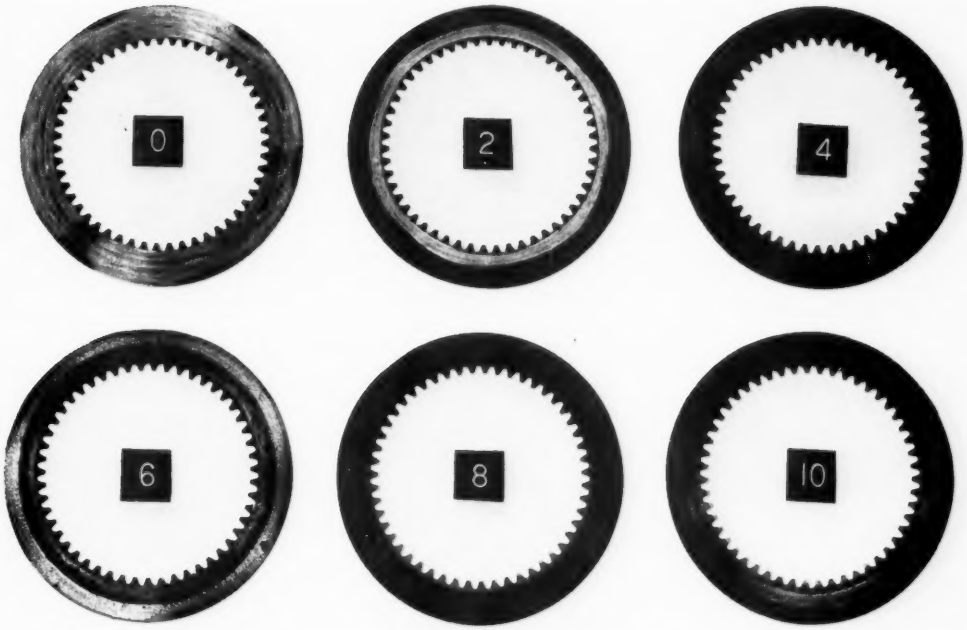

Figure 14 — Reference standard for the numerical rating of Hydra-Matic clutch plate condition (No. 10 is best).

One of the major advantages of this type test arises from the fact that the inertia wheel permits a close approximation of transmission loading occurring in a car on the road. Figure 16 shows a plot of engine speed versus transmission speed obtained with a Moseley X-Y Recorder. Three consecutive cycles are shown on the curve, and the shift points are apparent. This same type of curve can be obtained from road operation and the laboratory and road curves can be made to coincide through proper adjustment of the flywheel inertia.

Another advantage of the Jet-Away Inertia Type Test is that it provides a means for obtaining information on the anti-squawk characteristics of automatic transmission fluids. The so-called "squawk" or "chatter" is a noise emanating from the stick-slip action of the clutch plates when engaged under torque conditions. Aside from being a noise which might annoy some car operators, squawk is an indication of an undesirable shift characteristic which is far more objectionable than the noise itself.

Figure 17 shows high speed traces (chart speeds of 50 mm per second) made of the 2-3 shift during a run when the transmission was squawking. A momentary hand switch connected to an event marker pen on the oscillograph was depressed when squawk was heard, in order to establish at what point during the 2-3 shift squawk occurred. It can be seen that the marks were within 1/10 of a second (equal to five revolutions of the engine at 3000 rpm) of being at the same point on the engine speed trace and that squawk occurs at or just before complete engagement of third gear.

SQUAWK TESTS

In the development of automatic transmission fluids at a large petroleum research center during the

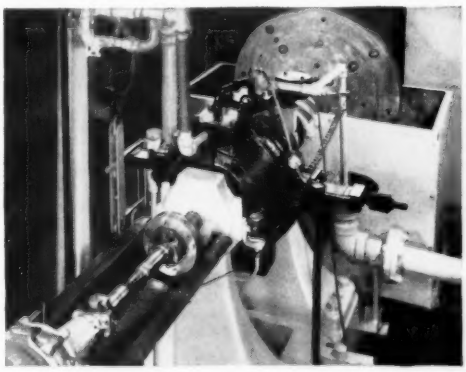

Figure 15 — Dynamometer and inertia wheel used in 50 Hour (or 2400 cycle) Hydra-Matic Durability Cycling Test.

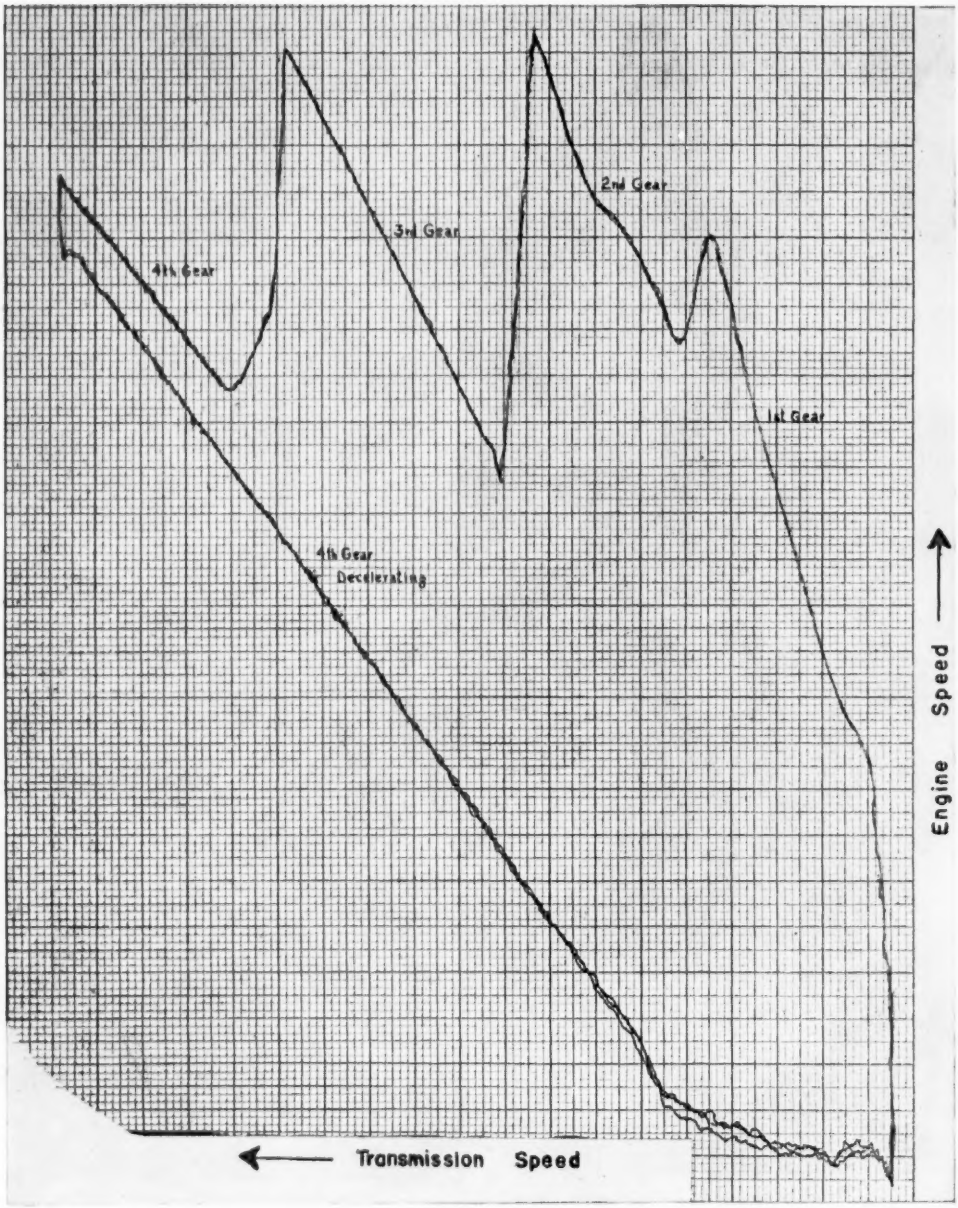

Figure 16 — Relationship between engine and Jet-Away transmission output speeds during Inertia Wheel Cycling Test.

past fifteen years, a simple squawk test procedure has been found which is very useful in evaluating this characteristic. Briefly, this test consists of flushing the transmission with test oil, filling with a fresh charge and making 75 accelerations on the highway or chassis dynamometer. Accelerations are alternated between approximately ⅓ throttle, 0-40 miles per hour and full throttle, 0-60 miles per hour.

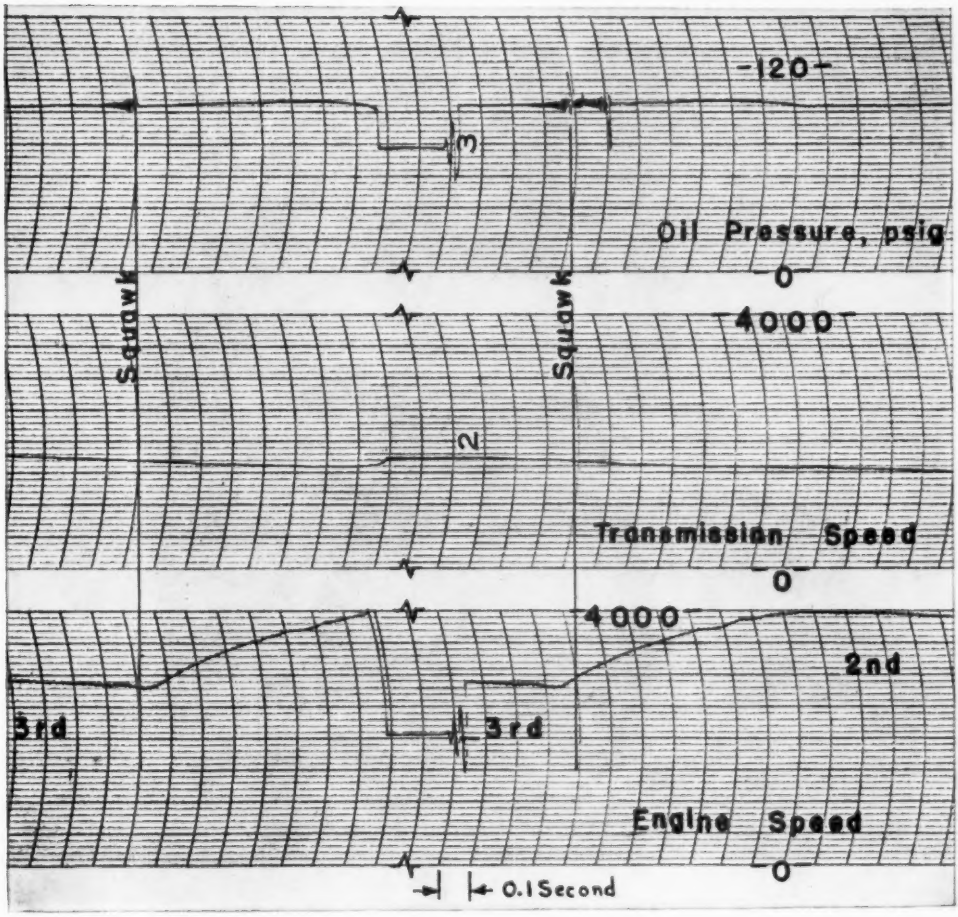

Figure 17 — High speed traces of transmission performance during Jet-Away Inertia Wheel Cycling Test.

Accelerations are regulated so that the transmission oil temperature increases from ambient to 275°F. during the test. If necessary, the temperature can be increased more rapidly by stalling the car with the brake while the engine is speeded up with the transmission in "Drive." It has been found very helpful to alternate test and reference runs, using a straight mineral oil for the reference, to ascertain if the transmission remains in squawking condition.

A squawk rating system was devised so as to permit assignment of a numerical rating based on the squawk intensity and frequency of occurrence. Numerical values were selected so that a rating of 300 is the maximum possible with 0 indicating no squawk.

ADDITIONAL REQUIREMENTS

In addition to the requirements set forth in the Type A and Type A, Suffix A Specifications, automatic transmission fluids often are called upon to satisfy other demands and to have supplementary characteristics.

Pump Wear Protection

In addition to lubricating and protecting against wear in the various transmissions, the automatic transmission fluid is usually expected to perform satisfactorily in various power steering pumps. The majority of these pumps are similar in type and require a high degree of wear protection by the fluid.

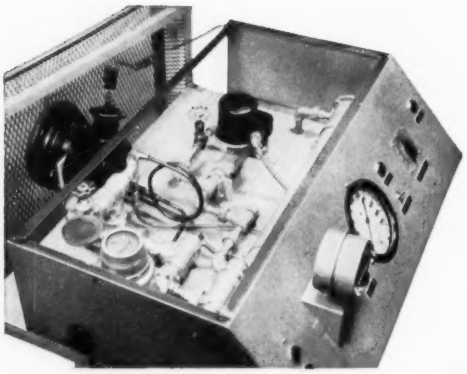

Figure 18 — Equipment for Saginaw 680 Hour Pump Durability Test.

The Saginaw 680 Hour Durability Test equipment is shown in Figure 18 and is probably the most severe measure of anti-wear protection afforded the power steering pump by the automatic transmission fluid. The procedure consists of 30 hours of simulated parking and 150 hours of simulated cornering, followed by 500 hours of operation at 1850 rpm and 500 psi discharge pressure.

Throughout the test, the pump flow rate is plotted periodically as shown in Figure 19. Constant surging or a substantial decrease in pump delivery rate constitute unsatisfactory operation, as does excessive weight loss of the various components.

Performance in Air-Ride Compressors

The introduction, in 1958, of air suspension systems for passenger cars imposed a further requirement on automatic transmission fluids. Since the air compressors in some of these systems share a common sump with the power steering pump, the automatic transmission fluid used in the power steering is called upon to lubricate air compressors operating at very high speeds, temperatures and pressures.

As yet, no satisfactory or concise method has been evolved for evaluating the performance of fluids in air-ride compressors. However, it is hoped that the bench test pictured in Figure 20 and using an electrically-driven 1958 Pontiac two-cylinder air compressor, may prove to be a step toward the development of such a method.

Special Requirements

Because of certain conditions, some automotive manufacturers have special requirements for automatic transmission fluids. Such requirements include water insensitivity, close viscosity control and color.

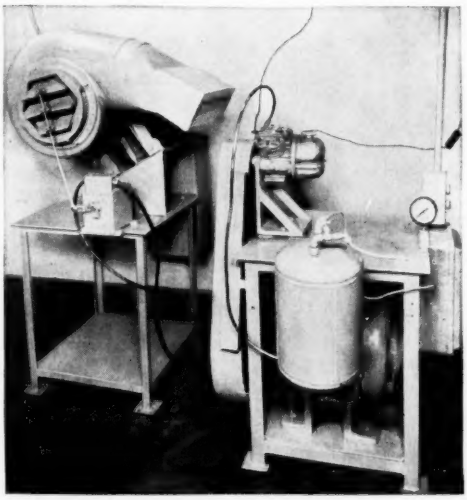

Figure 20 — Equipment for Air-Ride Compressor Test.

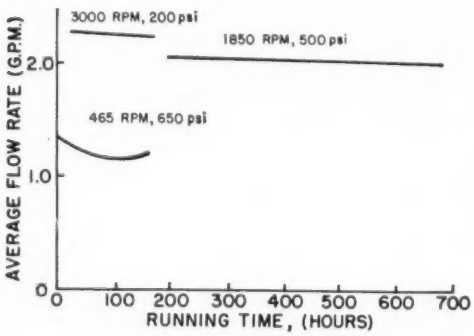

Figure 19 — Characteristic pump performance during Saginaw 680 Hour Test.

Because of their special and individual nature such requirements are not discussed in this article.

SUMMARY

In addition to the purposes mentioned previously, this article was designed to indicate what has happened in the past, what is the present status and what is the trend to the future in evaluating automatic transmission fluids. It is realized that, in this fast-moving field, some of the procedures may have been changed even since the article was written.

However, the foregoing article indicates that even the evaluation, to say nothing of the design, of automatic transmission fluids with their various requirements is a complicated matter.

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